Great Designs in

STEEL

Consideration of Damage Accumulated During the Forming Process in Crash Simulations

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GDIS2018

Damage accumulated during the forming

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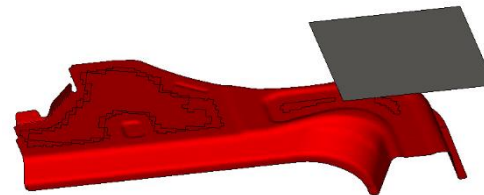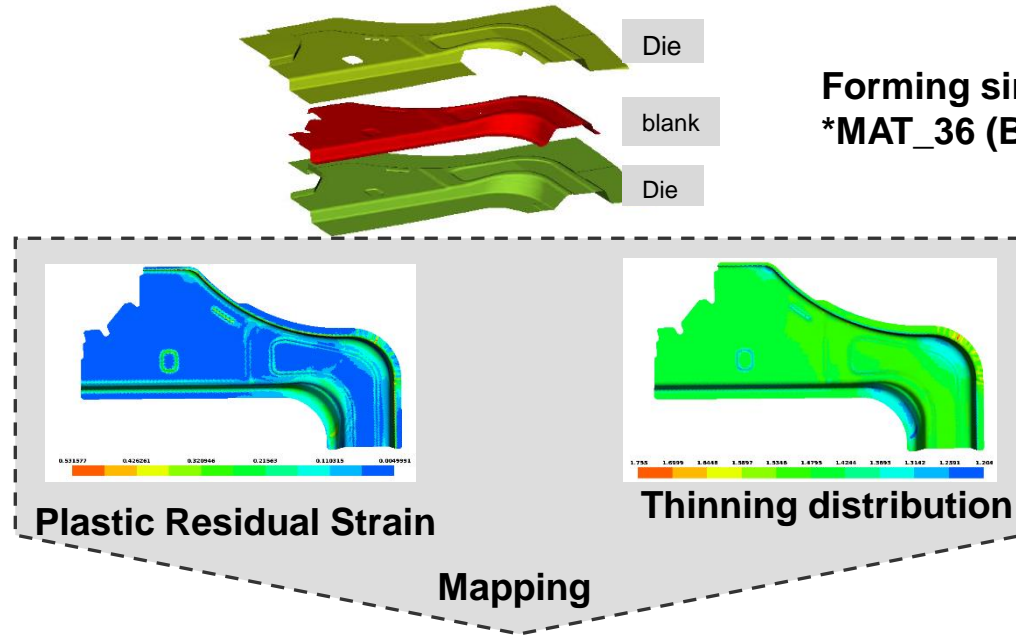
1. FCA US LLC, 1000 Chrysler DR, Auburn Hills, MI 48326
2. AK Steel Corporation, Advanced Engineering, RIC, 14661 Rotunda Dr, Dearborn, MI 48120
3. Engineering Technology Associates, Incorporated
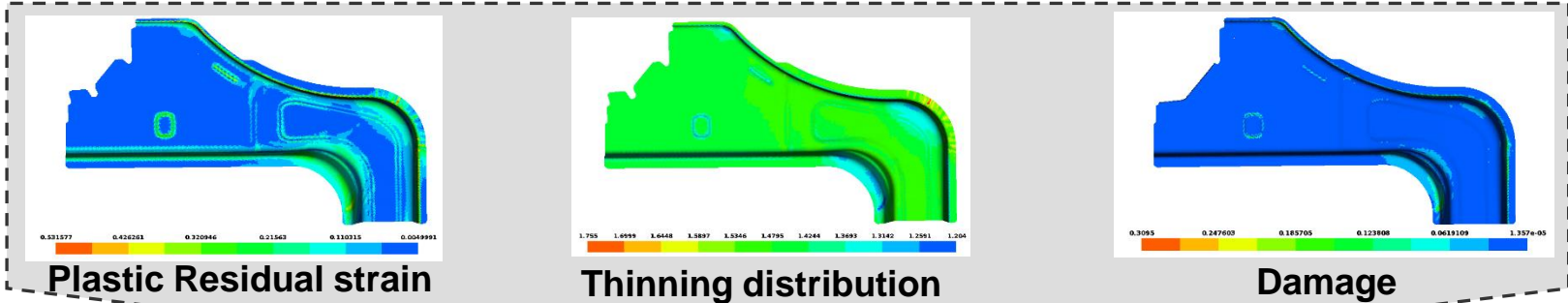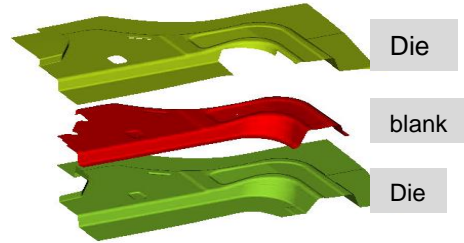
*presenter

Current Forming / Crash Integration Process

- **Formed parts undergo thinning and plastic Deformation**

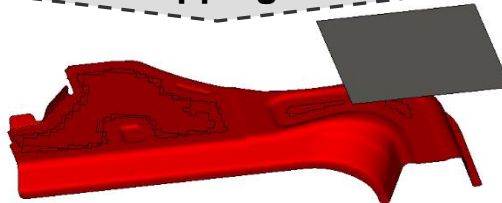- **The method of taking this into account in crash models is well established**

Die

blank

Die

Forming simulation:
*MAT_36 (Barlat '89)

Plastic Residual Strain

Thinning distribution

Mapping

Crash Simulation:
*MAT_24 (von Mises)

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Forming simulation:
*MAT_36 (Barlat '89)
*MAT_ADD_EROSION
(GISSMO)

Die

blank

Die

Plastic Residual strain

Thinning distribution

Damage

Mapping

Crash Simulation:
*MAT_24 (Von Mises)
*MAT_ADD_EROSION
(GISSMO)

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Damage measures the reduction of the cross section by formation of pores and/or cracks

A = undeformed cross section

A_0 = deformed or current cross section

$A_{eff} = A(1 - D)$ = effective cross section

If D=1 the material has failed as a macrocrack has developed

In a so-called coupled damage formulation the stress is computed as follows :

$$\sigma = \frac{F}{A}$$ = true stress relates to true cross section

$$\sigma_{eff} = \frac{F}{A_{eff}} = \frac{\sigma}{1 - D}$$ = effective stress relates to effective cross section (undamaged material)
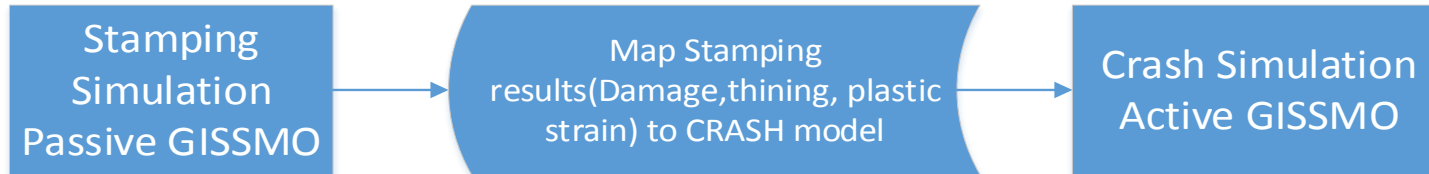
Damage is computed based on a failure criterion and a damage evolution law calibrated using coupon testing :
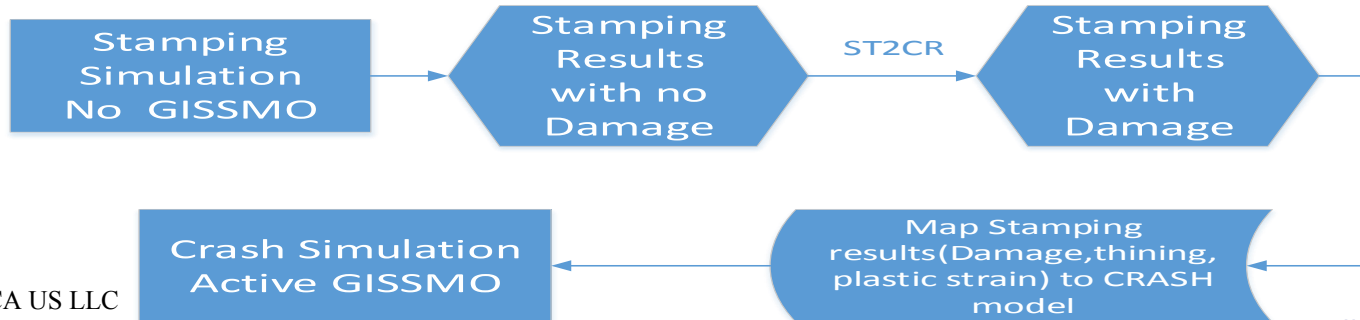
©2018 FCA US LLC
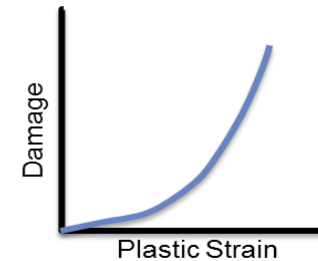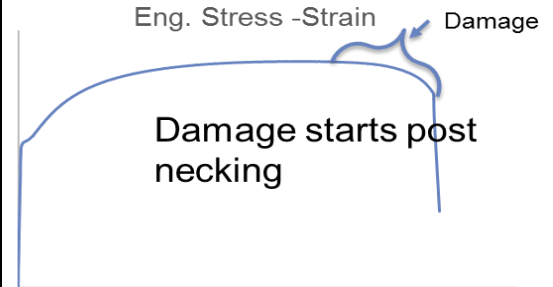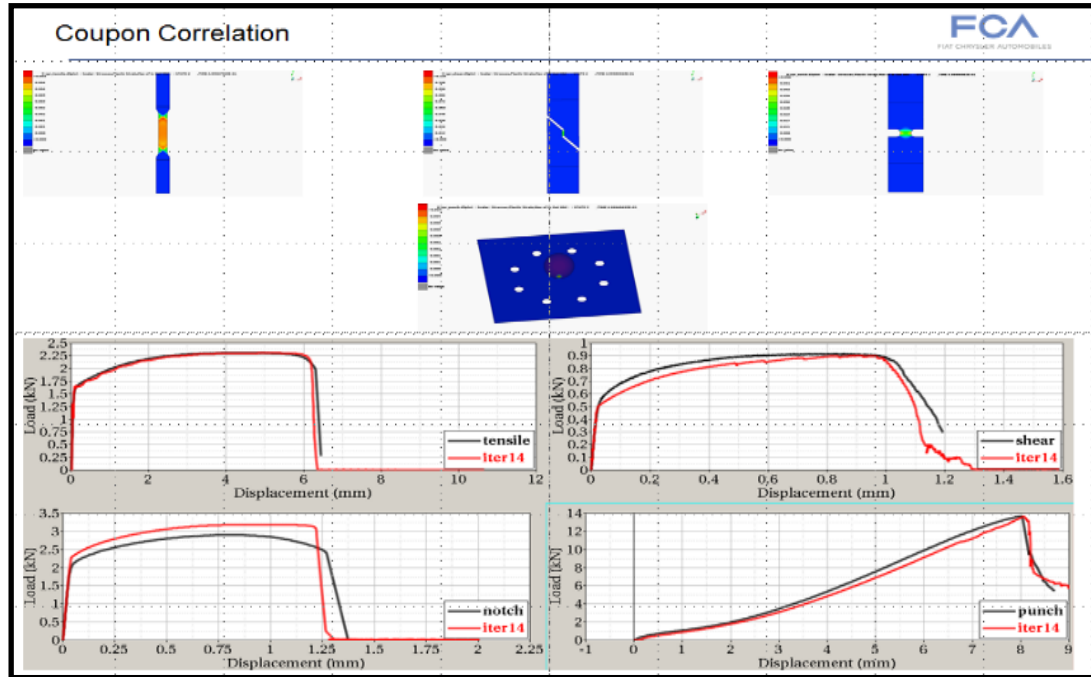
Approaches for Damage Assessment

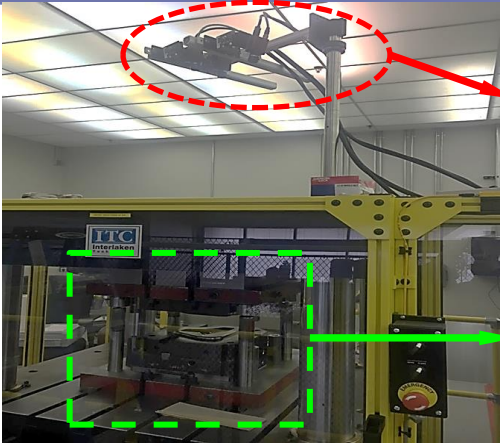Damage accumulated during the forming process can be determined by:

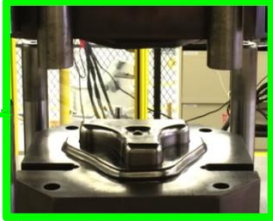1) **Performing incremental stamping simulation using GISSMO to extract accumulated damage.**

```
┌──────────────┐      ╭─────────────────────╮      ┌──────────────┐
│  Stamping    │      │   Map Stamping      │      │Crash Simulation│
│  Simulation  │ ───> │ results(Damage,     │ ───> │ Active GISSMO │
│Passive GISSMO│      │ thining, plastic    │      │              │
│              │      │ strain) to CRASH    │      │              │
└──────────────┘      │      model          │      └──────────────┘
                      ╰─────────────────────╯
```

2) **Perform incremental stamping simulation without GISSMO and   generate damage through a automated subroutine ST2CR.**

```
┌──────────────┐    ⬡ Stamping ⬡    ST2CR    ⬡ Stamping ⬡
│  Stamping    │      Results              Results
│  Simulation  │ ──>  with no      ──>      with
│  No GISSMO   │      Damage                Damage
└──────────────┘
```
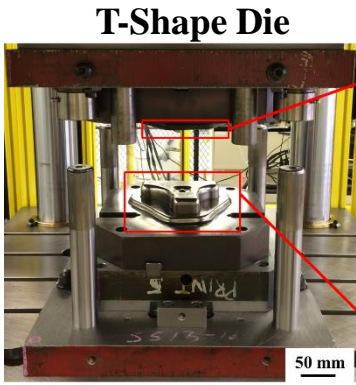
```
┌──────────────┐      ╭─────────────────────╮
│Crash Simulation│    │   Map Stamping      │
│ Active GISSMO │ <── │ results(Damage,     │ <──
│              │      │ thining, plastic    │
└──────────────┘      │ strain) to CRASH    │
                      │      model          │
                      ╰─────────────────────╯
```

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3 Camera DIC System
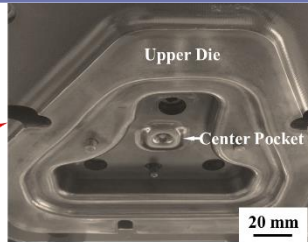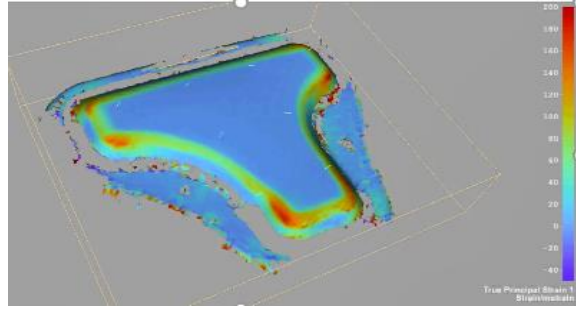
Interlaken Servo Hydraulic Press Double Motion

T-Shape Die

T-Shape Die

Upper Die

Center Pocket

20 mm

(b)
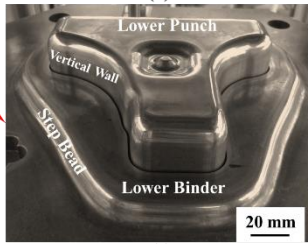
Lower Punch

Vertical Wall

Step Bead

Lower Binder

20 mm

(c)

50 mm
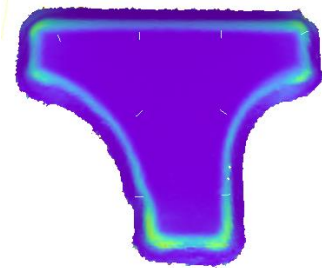
(a)

1.2 mm Thickness

200

105

115

200

RD

70   90
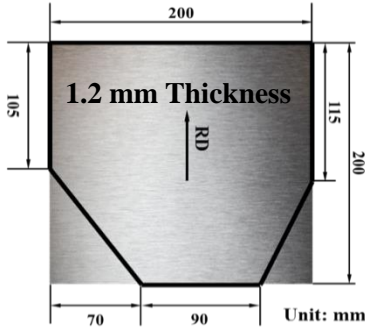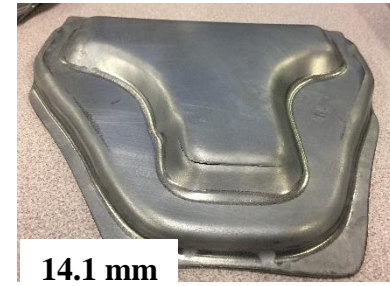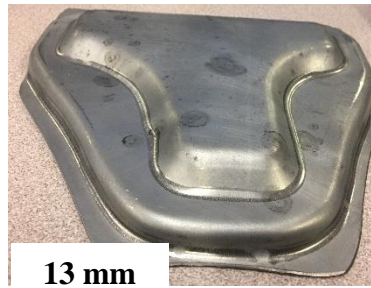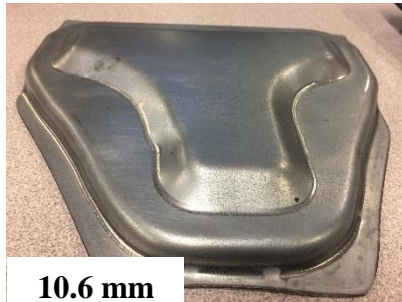
Unit: mm

Evolution of Major Strain Distribution Determined by ex situ DIC

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- Fabricate stamped T- section parts at different draw depths to represent safe, marginal and unacceptable parts for DP-980 material. The binder gap was kept as a constant, 110 % of the blank thickness.
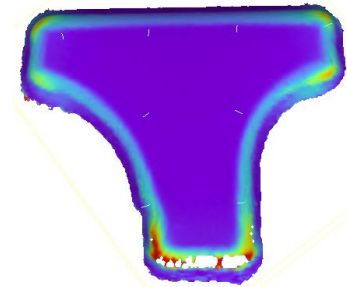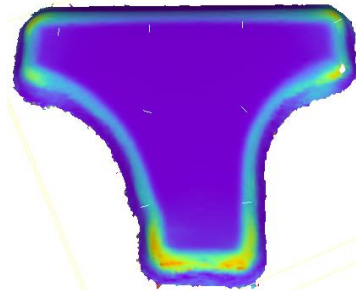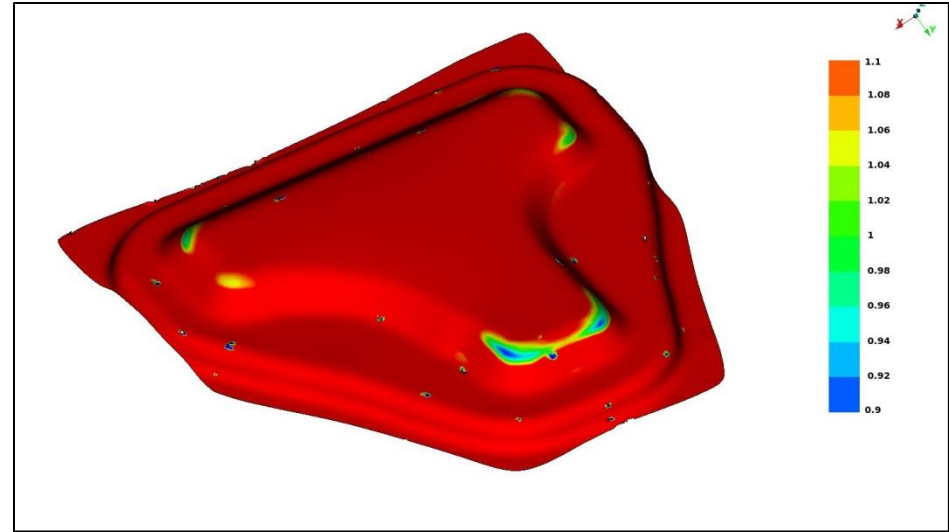

10.6 mm

13 mm

14.1 mm

Evolution of Major Strain Distribution Determined by ex situ DIC

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- Incremental stamping and scanned part shows close correlation on thickness variation
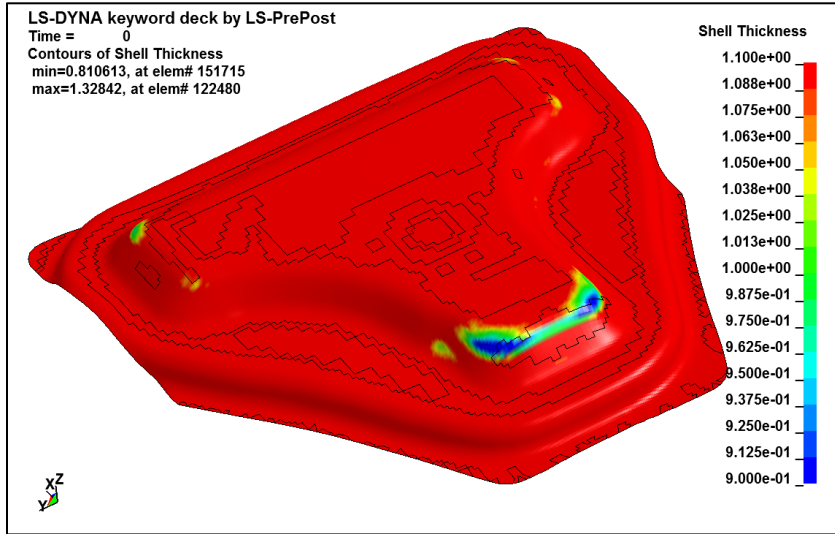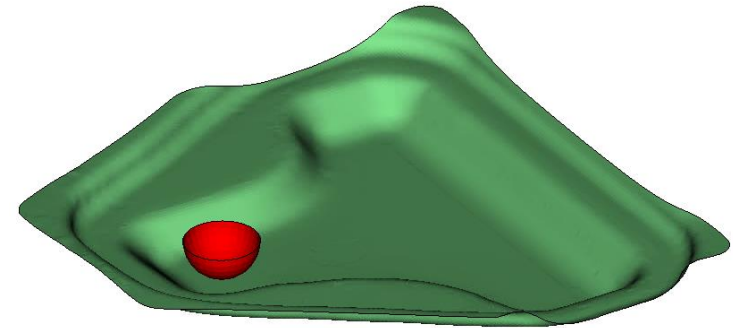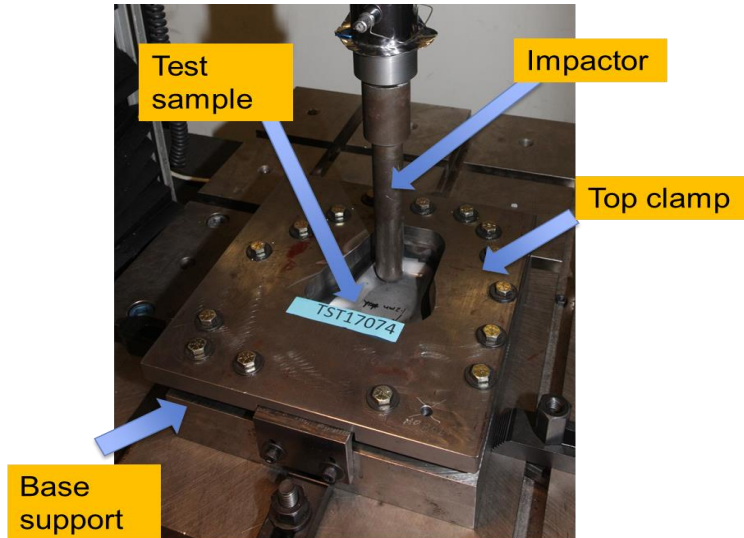

LS-DYNA prediction

scanned values

- Conduct test to deform the part at damage location induced during forming.
- Perform forming and crash simulation to duplicate test and demonstrate effect of damage by comparing failure with and without damage.
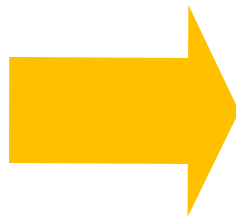

Test sample

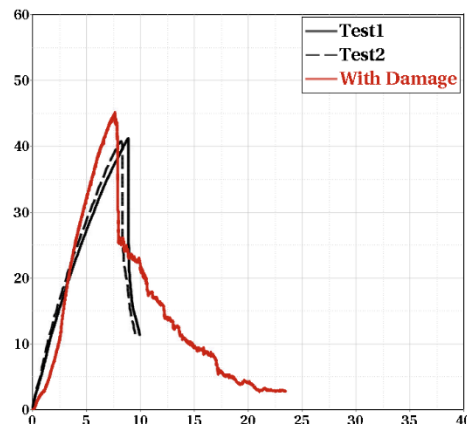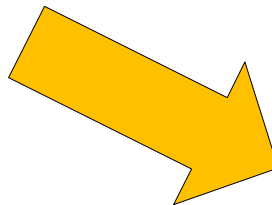Impactor

Top clamp

TST17074

Base support
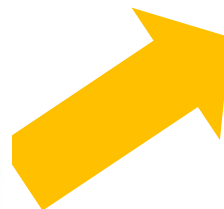
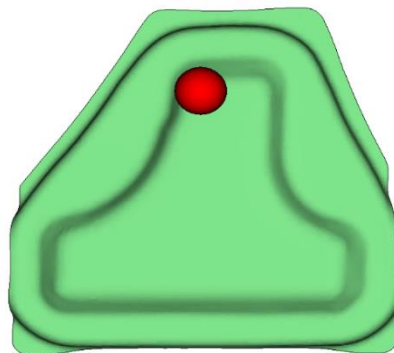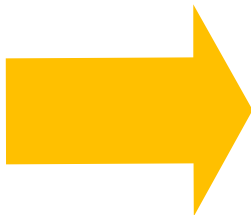Finite Element Model

Test

Fabricate part at safe
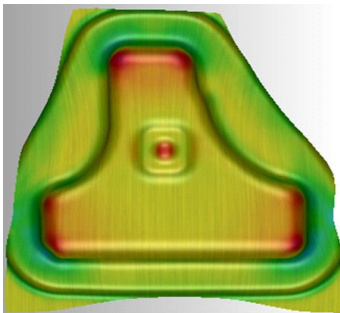and marginal draw
depths

Conduct test to break part
at high damage area

Simulation

Simulation and
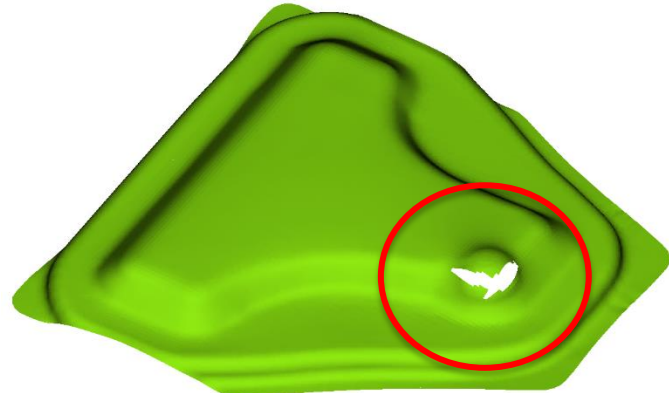test comparison

Post Test –Simulation Comparison

Test

Finite Element Model

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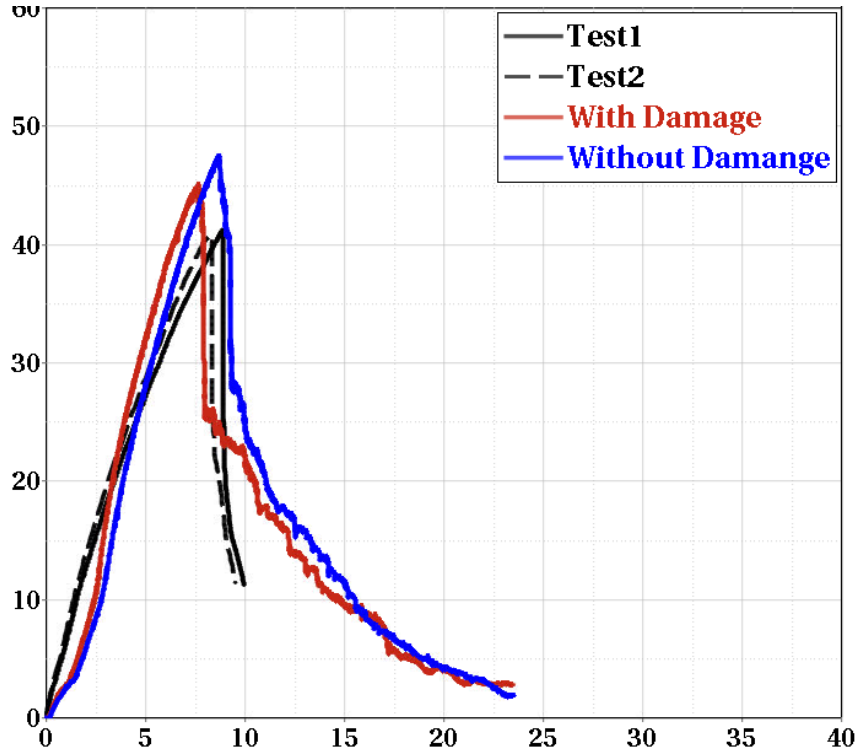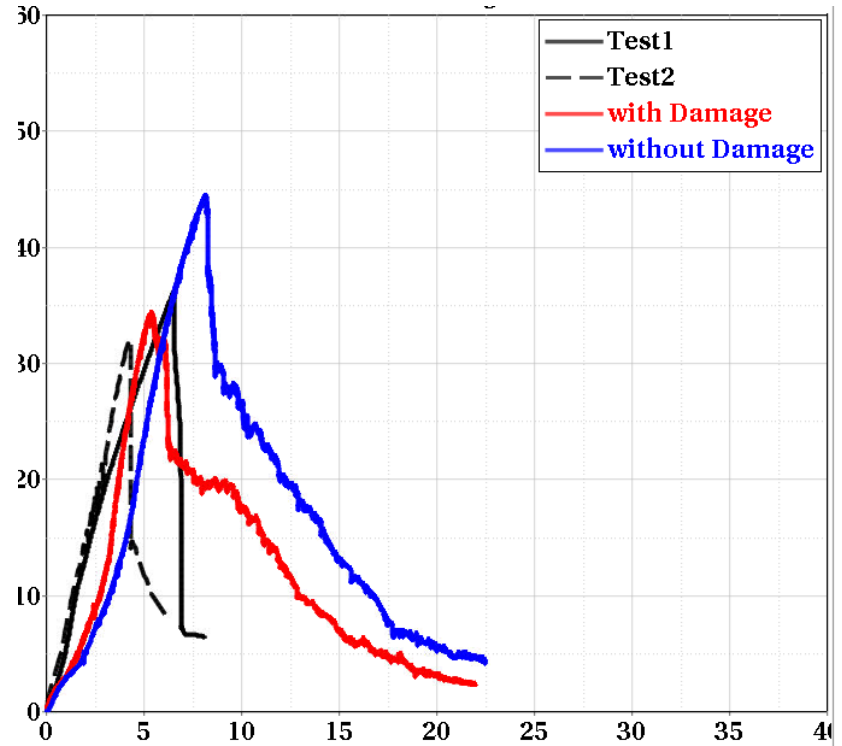
Load – Deflection Comparison

Draw Depth 10.6 mm – Minimally damaged

Draw Depth 13 mm – Marginally damaged

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Post Forming Simulation Estimate of Damage

- Sometimes the damage values will not be available from the forming simulation

- A program <u>Stamping to Crash</u> (ST2CR) was developed to estimate the damage from the final results of the stamping simulation
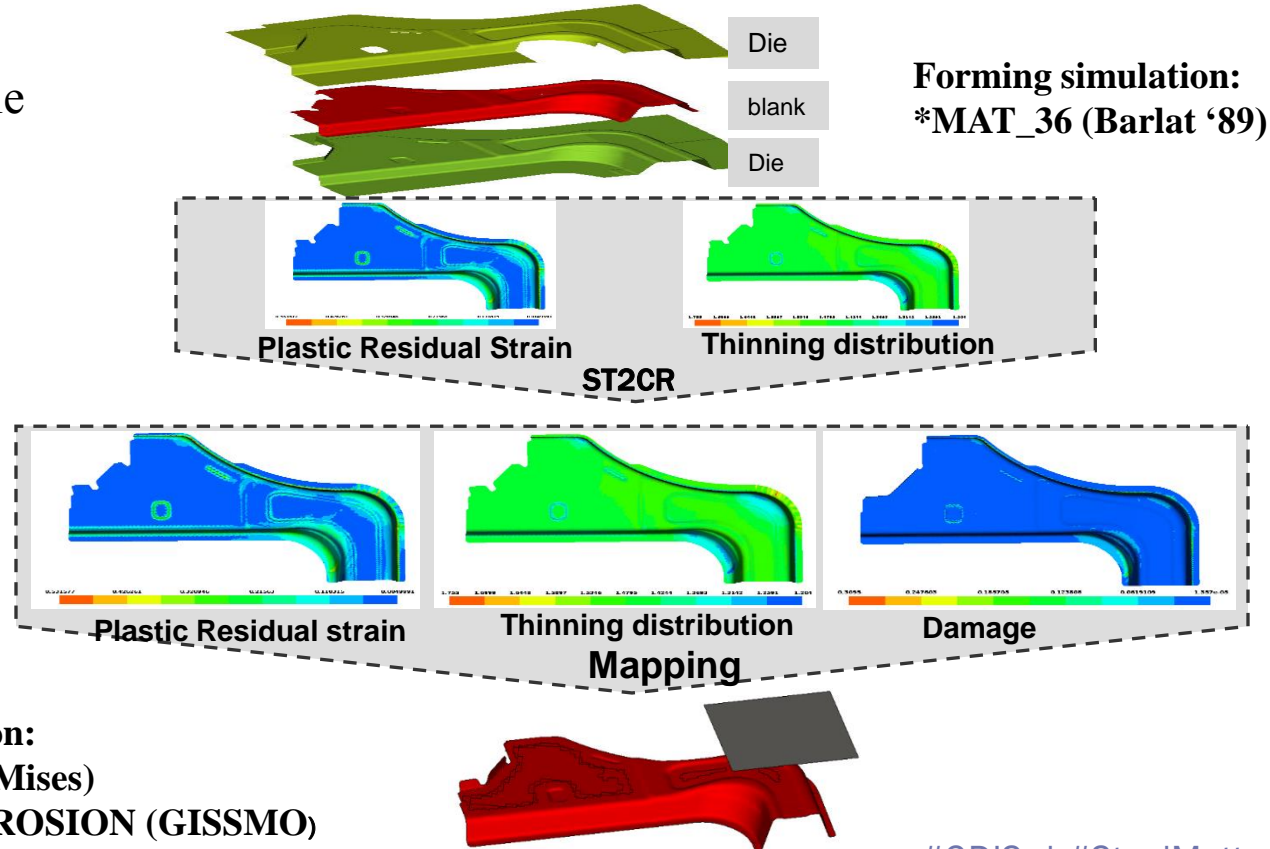
Forming simulation:
*MAT_36 (Barlat '89)

Die

blank

Die

Plastic Residual Strain   **Thinning distribution**

ST2CR

Plastic Residual strain   **Thinning distribution**   **Damage**
Mapping

Crash Simulation:
*MAT_24 (von Mises)
*MAT_ADD_EROSION (GISSMO)

- Comparison between computed and estimated (ST2CR) damage:

5.191e-01
4.866e-01
4.542e-01
4.217e-01
3.893e-01
3.569e-01
3.244e-01
2.920e-01
2.595e-01
2.271e-01
1.947e-01
1.622e-01
1.298e-01
9.733e-02
6.488e-02
3.244e-02
5.349e-08

From incremental simulation

From automation script

- Comparison between computed and estimated (ST2CR) damage:

From incremental simulation

From automation script
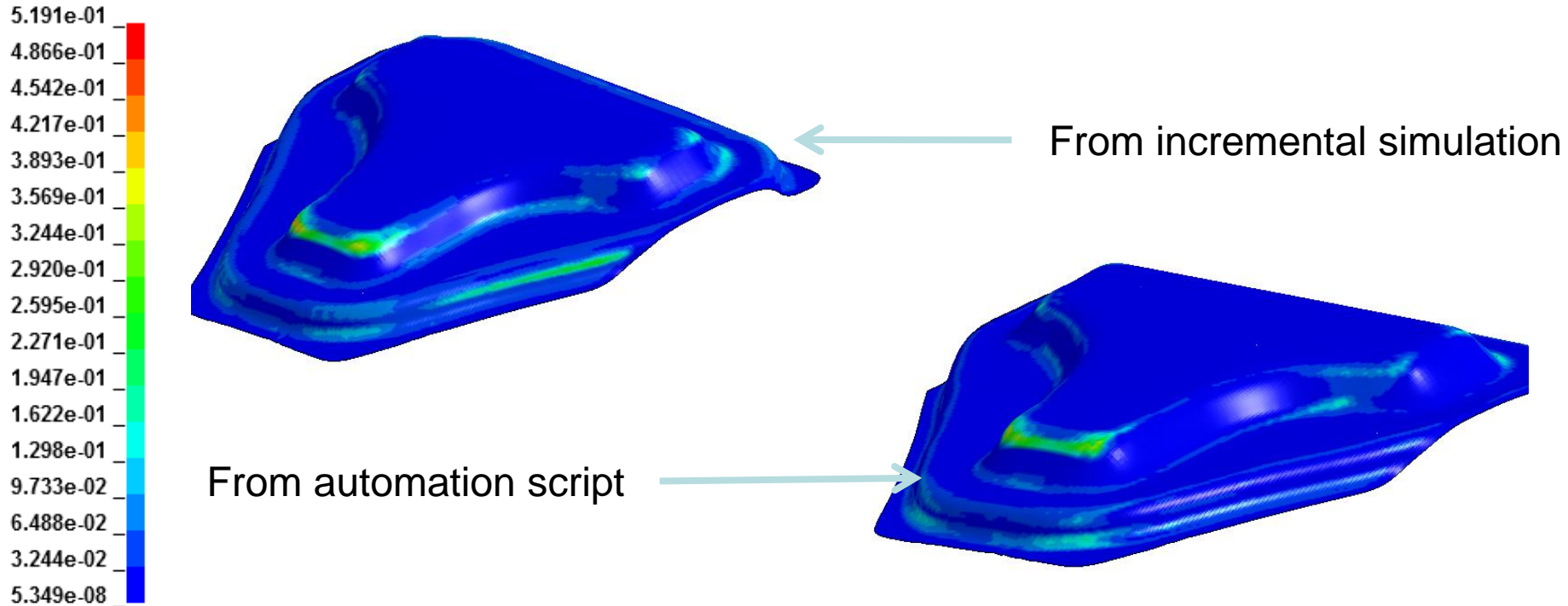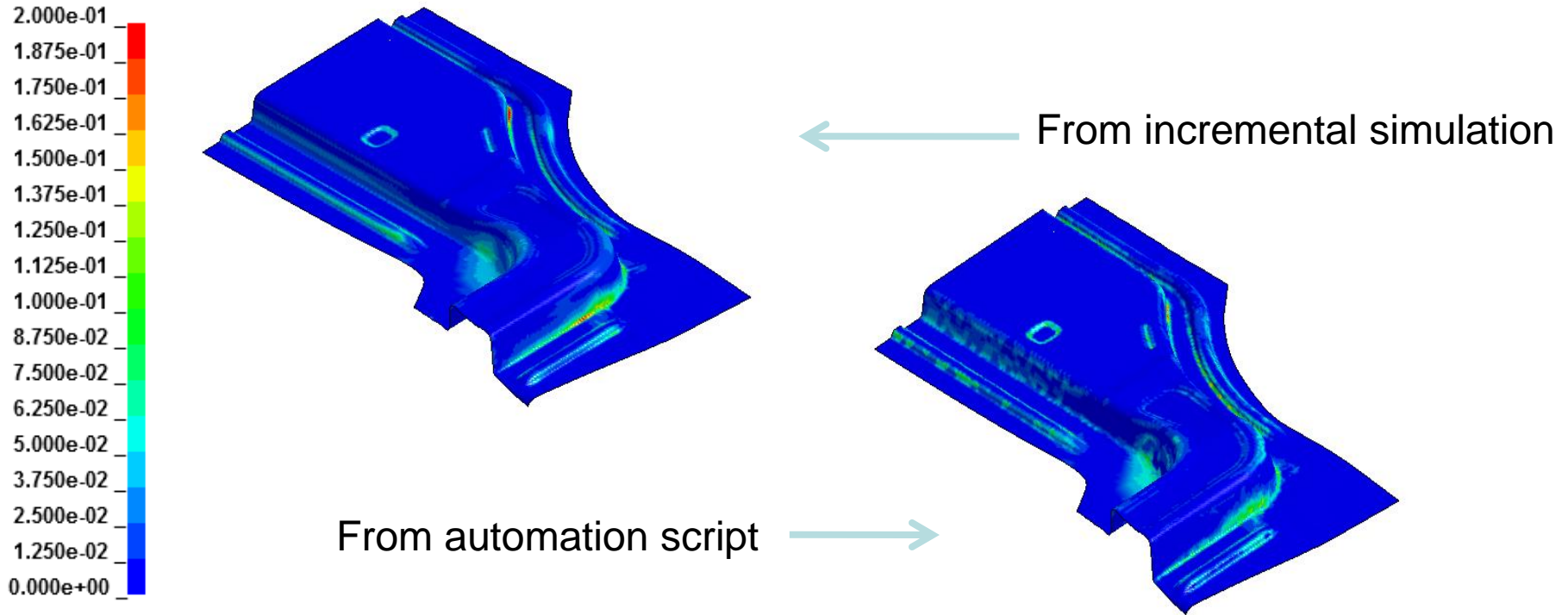
Thank You

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